PB-242 538

ST. LOUIS BAY, ST. LOUIS COUNTY, MINNESOTA, AND DOUGLAS COUNTY, WISCONSIN

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center

May 1975

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NATIONAL EUTROPHICATION SURVEY

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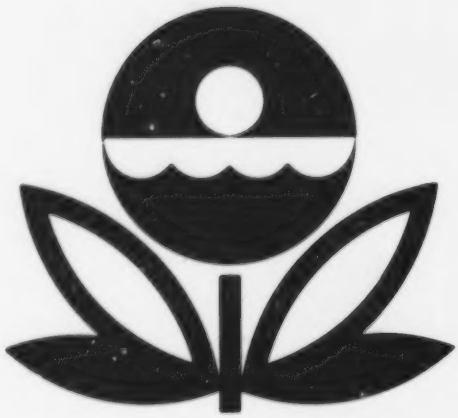

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT
ON
ST. LOUIS BAY
ST. LOUIS COUNTY, MINNESOTA,
AND
DOUGLAS COUNTY, WISCONSIN

EPA REGION V

WORKING PAPER No. 123

WITH THE COOPERATION OF THE

MINNESOTA POLLUTION CONTROL AGENCY

AND THE

MINNESOTA NATIONAL GUARD

MAY, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Minnesota Pollution Control Agency for professional involvement and to the Minnesota National Guard for conducting the tributary sampling phase of the Survey.

Grant J. Merritt, Director of the Minnesota Pollution Control Agency, John F. McGuire, Chief, and Joel G. Schilling, Biologist, of the Section of Surface and Groundwater, Division of Water Quality, provided invaluable lake documentation and counsel during the course of the Survey; and the staff of the Section of Municipal Works, Division of Water Quality, were most helpful in identifying point sources and soliciting municipal participation in the Survey.

Major General Chester J. Moeglein, the Adjutant General of Minnesota, and Project Officer Major Adrian Beltrand, who directed the volunteer efforts of the Minnesota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

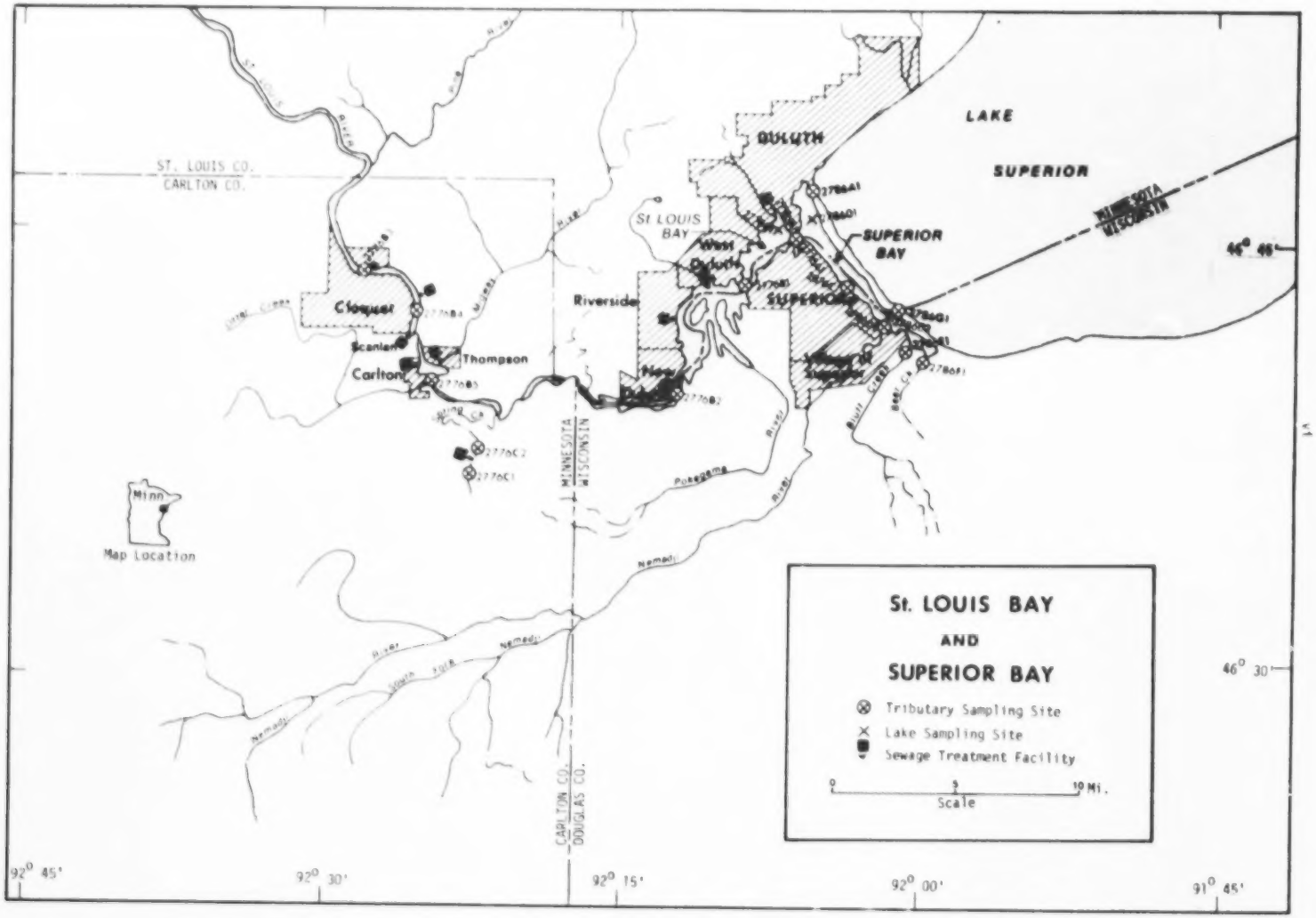
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MINNESOTA

LAKE NAME	COUNTY
Albert Lea	Freeborn
Andrusia	Beltrami
Badger	Polk
Bartlett	Koochiching
Bear	Freeborn
Bemidji	Beltrami
Big	Stearns
Big Stone	Big Stone, MN; Roberts, Grant, SD
Birch	Cass
Blackduck	Beltrami
Blackhoof	Crow Wing
Budd	Martin
Buffalo	Wright
Calhoun	Hennepin
Carlos	Douglas
Carrigan	Wright
Cass	Beltrami, Cass
Clearwater	Wright, Stearns
Cokato	Wright
Cranberry	Crow Wing
Darling	Douglas
Elbow	St. Louis
Embarass	St. Louis
Fail	Lake
Forest	Washington
Green	Kandiyohi
Gull	Cass
Heron	Jackson
Leech	Cass
Le Homme Dieu	Douglas
Lily	Blue Earth
Little	Grant
Lost	St. Louis

LAKE NAME	COUNTY
Madison	Blue Earth
Malmedal	Pope
Mashkenode	St. Louis
McQuade	St. Louis
Minnetonka	Hennepin
Minnewaska	Pope
Mud	Itasca
Nest	Kandiyohi
Pelican	St. Louis
Pepin	Goodhue, Wabasha, MN; Pierce, Pepin, WI
Rabbit	Crow Wing
Sakatah	Le Sueur
Shagawa	St. Louis
Silver	McLeod
Six Mile	St. Louis
Spring	Washington, Dakota
St. Croix	Washington, MN; St. Croix, Pierce, WI
St. Louis Bay	St. Louis, MN; Douglas, WI
Superior Bay	St. Louis, MN; Douglas, WI
Swan	Itasca
Trace	Todd
Trout	Itasca
Wagonga	Kandiyohi
Wallmark	Chisago
White Bear	Washington
Winona	Douglas
Wolf	Beltrami, Hubbard
Woodcock	Kandiyohi
Zumbro	Olmstead, Wabasha


ST. LOUIS CO.
CARLTON CO.
DULUTH
LAKE
SUPERIOR
ST LOUIS
BAY
West
Duluth
SUPERIOR
BAY
MINNESOTA
WISCONSIN
46° 45'
Cloquet
Scanlon
Carlton
Thompson
Riverside
SUPERIOR
Minn
Map Location
Pokegama
Nemadji
CARLTON CO.
DOUGLAS CO.
St. LOUIS BAY
AND
SUPERIOR BAY
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
0
5
10 Mi.
Scale
46° 30'
92° 45'
92° 30'
92° 15'
92° 00'
91° 45'

ST. LOUIS BAY

STORET NO. 2776

I. CONCLUSIONS

A. Trophic Condition:

Survey data show that St. Louis Bay is eutrophic. Of the 60 Minnesota lakes sampled in the fall of 1972, when essentially all were well-mixed, 52 had less mean total phosphorus, 50 had less mean dissolved phosphorus, and 55 had less mean inorganic nitrogen. For all Minnesota data, 53 lakes had greater Secchi disc transparency, and all but three lakes had higher mean chlorophyll a. This apparent anomaly probably is due to the very low transparency observed in St. Louis Bay and a resulting light inhibition of algal growth.

Survey limnologists observed floating and suspended solids, oil films, much silting, and putrescent odors during the July and October sampling periods with some lessening of these conditions during the September sampling visit.

B. Rate-Limiting Nutrient:

Based on the results of the algal assay, primary productivity in St. Louis Bay was nitrogen limited at the time the sample was collected. Field data indicate nitrogen limitation during all three sampling periods (N/P ratios were 6/1 or less).

C. Nutrient Controllability:

1. Point sources--During the sampling year, St. Louis Bay received a total phosphorus load at a rate about 12 times that proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 13). However, Vollenweider's model probably is not applicable to water bodies with short hydraulic retention times, and the mean hydraulic retention time of St. Louis Bay is a very short six days. Nonetheless, the existing water quality in the bay is evidence of excessive nutrient loads.

It is calculated that the municipal point sources considered in this study contributed a little over 49% of the total phosphorus input to the bay during the sampling year. Industries and port traffic are believed to have contributed nutrients also, but the significance of these sources was not determined (see page 10).

The Western Lake Superior Sanitary District was organized in 1974 and will ultimately construct a tertiary wastewater treatment plant at the site of the existing Duluth main plant (McGuire, 1975). The new plant will provide treatment for all of the point sources considered in this report (page 10), as well as a few additional small discharges, and will be required

to meet the Minnesota Pollution Control Agency's mean effluent phosphorus limitation of 1 mg/l total phosphorus.

On the basis of measured and estimated municipal waste treatment plant flows, it is calculated that the required effluent phosphorus limitation will result in a 41% reduction of the overall total phosphorus load to St. Louis Bay. This reduction should result in marked improvement in the trophic condition of St. Louis Bay as well as significant enhancement of the water quality of downstream Superior Bay (see Working Paper No. 128, "Report on Superior Bay").

2. Non-point sources--During the sampling year, the phosphorus export rate of the St. Louis River was a somewhat high 96 lbs per square mile of drainage. In part, this probably resulted from the unmeasured minor discharges, industrial wastes, and port traffic noted above.

In all, it is estimated that non-point sources contributed nearly 51% of the total phosphorus load to St. Louis Bay.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 2,419 acres.
2. Mean depth: 11.1 feet.
3. Maximum depth: 25.0 feet.
4. Volume: 26,858 acre-feet.
5. Mean hydraulic retention time: 6 days.

B. Tributary and Outlet:
(See Appendix A for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
St. Louis River	3,670.0 mi^2	2,378.6 cfs
Minor tributaries & immediate drainage -	16.2 mi^2	17.8 cfs
Totals	3,686.2 mi^2	2,396.4 cfs

2. Outlet -

St. Louis Bay - Superior Bay Connection	3,692.7 mi^2**	2,396.4 cfs

C. Precipitation***:

1. Year of sampling: 25.5 inches.
2. Mean annual: 25.0 inches.

---

† Planimetered from U.S. Geological Survey map (1954); mean depth by random-dot method.

* Drainage areas are accurate within ±5%; mean daily flows are accurate within ±10%; and ungaged flows are accurate within ±10 to 25% for drainage areas greater than 10 mi^2.

** Includes area of lake.

*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

St. Louis Bay was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from one station on the bay and from a number of depths (see map, page vi). During each visit, a single depth-integrated (15 feet or near bottom to surface) sample was collected for phytoplankton identification and enumeration; and during the last visit, a single five-gallon depth-integrated sample was collected for algal assays. Also each time, a depth-integrated sample was taken for chlorophyll a analysis. The maximum depth sampled was 23 feet.

The results obtained are presented in full in Appendix B, and the data for the fall sampling period, when the bay essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix B.

A. Physical and chemical characteristics:

FALL VALUES

(10/18/72)

Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	7.0	7.0	7.0	7.0
Dissolved oxygen (mg/l)	7.7	7.7	7.7	7.7
Conductivity (µmhos)	165	165	165	165
pH (units)	7.3	7.3	7.3	7.3
Alkalinity (mg/l)	39	41	41	42
Total P (mg/l)	0.330	0.331	0.331	0.332
Dissolved P (mg/l)	0.235	0.241	0.241	0.248
NO_2 + NO_3 (mg/l)	0.110	0.110	0.110	0.110
Ammonia (mg/l)	1.320	1.350	1.350	1.380
		ALL VALUES		
Secchi disc (inches)	8	17	12	32

B. Biological characteristics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
09/06/72	1. Flagellates	85
	2. Dinobryon	67
	3. Cryptomonas	20
	4. Chroococcus	18
	5. Synedra	18
	Other genera	81
	Total	289
10/18/72	1. Flagellates	1,583
	2. Synedra	979
	3. Anabaena	930
	4. Melosira	904
	5. Chroococcus	377
	Other genera	1,257
	Total	6,030

* The July sample was lost in shipment.

2. Chlorophyll *a* -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll *a* (µg/l)
07/13/72	01	9.8
09/07/72	01	0.7
10/18/72	01	3.5

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.210	0.790	27.2
0.010 P	0.220	0.790	27.4
0.020 P	0.230	0.790	23.9
0.050 P	0.260	0.790	25.7
0.050 P + 5.0 N	0.260	5.790	98.0
0.050 P + 10.0 N	0.260	10.790	142.1
10.0 N	0.210	10.790	112.5

2. Discussion -

The control yield of the assay alga, *Selenastrum capricornutum*, indicates that the potential primary productivity was high at the time the sample was collected. The lack of increase in yield when orthophosphorus was added and the significant increase in yield when only nitrogen was added indicate nitrogen limitation.

Field data indicate nitrogen limitation at all sampling periods (i.e., the N/P ratios were 6/1 or less, and nitrogen limitation would be expected).

IV. NUTRIENT LOADINGS
(See Appendix C for data)

For the determination of nutrient loadings, the Minnesota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi). Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Minnesota District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the means of the nutrient loads, in $lbs/mi^2/year$, in Bluff Creek (tributary to Superior Bay) at station E-1 and multiplying the means by the ZZ area in mi^2.

The operators of the Duluth and Cloquet wastewater treatment plants provided monthly effluent samples and corresponding flow data. Nutrient loads attributed to the Duluth West plants were estimated on the basis of combined flows and composited samples from the Fairmont, Smithville, and Gary-New Duluth wastewater treatment plants. However, the operators

* See Working Paper No. 1.

of the Scanlan, Carlton, Thompson Township, and Wrenshall treatment plants did not participate in the Survey, and nutrient loads from those sources were estimated at 2.5 lbs P and 7.5 lbs N/capita/year.

Nutrient loads shown for the St. Louis River are those measured at station B-1 minus the known upstream point sources.

A. Waste Sources:

1. Known municipal† -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Duluth Main	100,578	prim. clarifier	16.125	St. Louis Bay
Cloquet	8,699	prim. clarifier	1.649	St. Louis River
Duluth West plants*	11,490	prim. clarifier	1.149	St. Louis Bay
Scanlan	1,132	Imhoff tank	0.113**	St. Louis River
Carlton	844	prim. clarifier	0.084**	St. Louis River
Thompson Township	159	act. sludge	0.016**	St. Louis River
Wrenshall	147	stab. ponds	0.015**	Silver Creek

2. Industrial - A number of industries discharge wastes either directly to the St. Louis River or Bay or to some of the municipal wastewater treatment plants (Anonymous, 1969a); because of the constraints of the Survey***, nutrient contributions from these sources were not evaluated.

Also, nutrients may be contributed by ships in port (Miller, 1965), but the significance of these sources was not assessed.

† Anonymous, 1974.
* Fairmont, Smithville, and Gary-New Duluth sewage treatment plants.
** Estimated at 100 gal/capita/day.
*** See Working Paper No. 1.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
St. Louis River	353,320	50.3
b. Minor tributaries & immediate drainage (non-point load) -	3,780	0.5
c. Known municipal STP's -		
Duluth Main	270,400	38.5
Cloquet	45,480	6.5
Duluth West plants	23,160	3.3
Scanlan	2,830	0.4
Carlton	2,110	0.3
Thompson Township	400	<0.1
Wrenshall	370	<0.1
Port traffic* -	?	-
d. Septic tanks - Unknown	?	-
e. Industrial - Unknown	?	-
f. Direct precipitation** -	380	<0.1
Total	702,230	100.0

2. Outputs -

Lake outlet - Superior Bay inlet 499,550

3. Net annual P accumulation - 202,680 pounds

* Wastes discharged from ships in port.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
St. Louis River	6,446,420	83.6
b. Minor tributaries & immediate drainage (non-point load) -	43,380	0.6
c. Known municipal STP's -		
Duluth Main	953,580	12.3
Cloquet	136,280	1.8
Duluth West plants	91,510	1.2
Scanlan	8,490	0.1
Carlton	6,330	0.1
Thompson Township	1,190	<0.1
Wrenshall	1,100	<0.1
Port traffic* - Unknown	?	-
d. Septic tanks - Unknown	?	-
e. Industrial - Unknown	?	-
f. Direct precipitation** -	23,300	0.3
Total	7,711,580	100.0

2. Outputs -

Lake outlet - Superior Bay inlet	7,645,580

3. Net annual N accumulation - 66,000 pounds

* Wastes discharged from ships in port.
** See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs $P/mi^2/yr$	lbs $N/mi^2/yr$
St. Louis River	96	1,757

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	290.3	83.7	3,187.9	24.5
grams/m^2/yr	32.54	9.38	357.3	2.7

Vollenweider loading rates for phosphorus ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of St. Louis Bay:

"Dangerous" (eutrophic rate)	2.70
"Permissible" (oligotrophic rate)	1.35

V. LITERATURE REVIEWED

Anonymous, 1969a. An appraisal of water pollution in the Lake Superior basin. FWPCA, U.S. Dept. Interior, Great Lakes Region, Chicago.

Anonymous, 1969b. Proceedings of the Conference in the Matter of Pollution of the Waters of Lake Superior and its Tributary Basin, Minnesota-Wisconsin-Michigan, vols. 1-4. FWPCA, U.S. Dept. Interior, Wash., D.C.

Anonymous, 1974. Wastewater disposal facilities inventory. MPCA, Minneapolis.

Kiester, C. E., S. C. Castagna, and Kenneth Mackenthun; 1961. Report on investigation of pollution of the St. Louis River, St. Louis Bay, and Superior Bay. MN Dept. of Health and WI State Board of Health.

McGuire, John F., 1975. Personal communication (treatment requirements in the St. Louis Bay area). MPCA, Minneapolis.

Miller, R. D., 1965. Report on investigation of pollution of the seaway Port of Duluth. MPCA, Minneapolis.

Vollenweider, Richard A., (in press). Input-output models. Schweiz. Z. Hydrol.

VII. APPENDICES

APPENDIX A

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2776 ST LOUIS BAY

TOTAL DRAINAGE AREA OF LAKE 3690.00

TRIBUTARY	SUB-DRAINAGE AREA	NORMALIZED FLOWS JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2776A1	3690.00	1004.00	988.00	1395.00	5656.00	5553.00	3873.00	2306.00	1798.00	1797.00	1785.00	1420.00	1148.00	2396.45
2776R1	3670.00	1002.00	987.00	1390.00	5618.00	5493.00	3824.00	2290.00	1791.00	1783.00	1774.00	1414.00	1143.00	2378.57
2776Z2	20.00	1.74	1.11	5.35	38.40	60.00	48.70	16.20	7.11	14.40	11.00	5.56	3.80	17.82

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 3690.00
SUM OF SUB-DRAINAGE AREAS = 3690.00

TOTAL FLOW IN = 28722.36
TOTAL FLOW OUT = 28723.00

NOTE *** TRIB 76A1=R6R1

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2776A1	10	72	2720.00	14	2450.00				
	11	72	3300.00	4	4750.00				
	12	72	2710.00	2	2760.00				
	1	73	1800.00						
	2	73	1790.00	4	1890.00				
	3	73	3230.00						
	4	73	3830.00	7	2730.00				
	5	73	5690.00	20	9250.00				
	6	73	2780.00	24	2180.00				
	7	73	1640.00						
	8	73	2430.00	25	1900.00				
	9	73	2430.00	23	1560.00				
2776R1	10	72	2700.00	14	2430.00				
	11	72	3290.00	4	4740.00				
	12	72	1405.00	2	1430.00				
	1	73	1800.00						
	2	73	1790.00	4	1890.00				
	3	73	3230.00						
	4	73	3800.00	7	2710.00				
	5	73	5630.00	20	9140.00				
	6	73	2740.00	24	2150.00				
	7	73	1630.00	24	1320.00				
	8	73	2420.00	25	1890.00				
	9	73	2410.00	23	1550.00				

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2776 ST LOUIS BAY

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
277677	10	72	16.70	14	15.00				
	11	72	12.80	4	18.00				
	12	72	4.67	2	4.80				
	1	73	0.97						
	2	73	0.58	4	0.90				
	3	73	2.30						
	4	73	26.10	7	19.00				
	5	73	61.20	20	99.00				
	6	73	35.10	24	28.00				
	7	73	11.50	28	9.30				
	8	73	9.60	25	7.50				
	9	73	19.40	23	12.40				

APPENDIX B

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 74/10/30

277601
46 45 12.0 092 07 06.0
ST LOUIS BAY
27 MINNESOTA

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2111202
0014 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/13	07 50	0000			32	170	6.40	47	0.220	0.740	0.295	0.204
	07 50	0004	18.2	4.8		160	6.40	46	0.210	0.580	0.184	0.122
	07 50	0010	17.8	2.0		190	6.30	56	0.220	1.440	0.760	0.600
72/09/07	10 30	0000			12	140	7.00	32	0.110	0.620	0.199	0.144
	10 30	0004	17.3	3.4		135	7.00	34	0.140	0.640	0.216	0.148
	10 30	0015	17.3	3.7		140	7.00	34	0.130	0.690	0.216	0.161
	10 30	0023	17.2	4.0		135	7.00	37	0.130	0.640	0.204	0.149
72/10/18	16 45	0000			8	165	7.30	39	0.110	1.320	0.332	0.248
	16 45	0004	7.0	7.7		165	7.30	42	0.110	1.380	0.330	0.235

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/13	07 50	0000	9.4J
72/09/07	10 30	0000	0.7J
72/10/18	16 45	0000	3.5J

J VALUE KNOWN TO BE IN ERROR

APPENDIX C

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 74/11/20

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27768A1 LS27768A1
46 45 00.0 092 06 00.0
ST LOUIS BAY/SUPERIOR BAY CONNT
27 15 DULTH/SUPRIOR
0/ST LOUIS BAY
US 53 BRDG BETW RICES PT & CONNORS PT
11[illegible]ALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	12 30		0.110	1.300	0.310	0.035	0.115
72/11/04	10 00		0.260	0.340	0.054	0.014	0.068
72/12/02	10 30		0.115	1.230	0.176	0.036	0.126
73/03/02	09 30		0.140	0.400	0.210	0.040	0.075
73/05/20	08 30		0.065	2.300	0.115	0.033	0.113
73/06/24	11 00		0.140	3.200	0.315	0.048	0.075
73/07/28	08 45		0.315	1.250	0.300	0.032	0.145
73/08/25	13 00		0.210	1.100	0.300	0.075	0.115
73/09/23	08 00		0.260	1.420	0.240	0.072	0.120

STORET RETRIEVAL DATE 73/10/30

277641 LS2776R1
46 43 00.0 092 08 30.0
ST LOUIS RIVER
27 15 SUPERIOR
1/ST LOUIS BAY
US 2 ARROWHEAD BRDG BELOW PROCTOR STP
11PALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	11 00		0.041	1.200	0.250	0.010	0.058
72/11/04	10 00		0.170	1.150	0.320	0.012	0.069
72/12/02			0.100	1.125	0.165	0.004	0.042
73/04/07	12 50		0.105	1.260	0.005K	0.013	0.135
73/05/20	12 00		0.038	1.781	0.115	0.010	0.065
73/06/24	12 30		0.054	1.320	0.339	0.026	0.055
73/07/28	12 30		0.176	1.540	0.380	0.060	0.120
73/08/25	10 00		0.093	1.200	0.290	0.034	0.085
73/09/23	07 15		0.189	1.320	0.370	0.052	0.115
	10 30		0.270	0.970	0.231	0.075	0.125

K VALUE KNOWN TO BE LESS THAN INDICATED

STORET RETRIEVAL DATE 74/1?/10

277042 LS277482
42 34 30.0 092 12 00.0
ST LOUIS RIVER
27 15 SUPERIOR
1/ST LOUIS BAY
ST HWY 23 BRDG E NEW DULUT AHV PRCTR STP
11FPALES 2111204
0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO3+NO2 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/11/14	10 15		0.052	1.150	0.140	0.010	0.063
72/11/04	10 45		0.730	1.330	0.310	0.014	0.073
73/04/07	13 30		0.140	0.150	0.005K	0.005K	0.010
73/06/24	12 00		0.056	1.470	0.340	0.029	0.065
73/07/24	13 00		0.174	1.470	0.390	0.063	0.125
73/08/25	10 30		0.085	1.200	0.244	0.035	0.085
73/09/23	10 00		0.172	1.330	0.390	0.052	0.115

K VALUE KNOWN TO BE LESS
THAN INDICATED

STORET RETRIEVAL DATE 74/10/30

277683 LS277683
45 43 30.0 092 28 00.0
ST LOUIS RIVER
27 7.5 CLOQUET
T/ST LOUIS BAY
ST HWY 33 BRDG N CLOQUET ABV STP
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	17 30		0.193	0.900	0.154	0.012	0.054
72/11/12	10 00		0.182	1.000	0.140	0.013	0.040
73/04/08	09 00		0.164	1.200	0.046	0.014	0.050
73/04/18	08 55		0.180	1.650	0.075	0.017	0.040
73/05/20	08 30		0.087	1.000	0.038	0.009	0.040
73/05/30	08 15		0.084	1.890	0.067	0.013	0.025
73/06/09	08 30		1.940	0.720	0.072	0.013	0.042
73/07/22	08 30		0.011	1.100	0.037	0.009	0.050
73/08/19	09 00		0.150	0.920	0.052	0.017	0.055

STORET RETRIEVAL DATE 74/10/30

277604 LS277604
45 42 10.0 092 25 00.0
ST LOUIS RIVER
27 7.5 CLOQUET
1/ST LOUIS MAY
US 61 BRDG E SCANLON
11 PALES 2111204
" 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO3&NO2 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	17	15	0.143	1.[illegible]	0.132	0.020	0.065
72/11/12	09	30	0.169	1.540	0.168	0.016	0.050
72/12/17	09	30	0.010K	1.150	0.021	0.008	0.075
73/01/21	08	30	0.147	1.[illegible]40	0.018	0.012	0.070
73/02/18	09	00	0.015		0.035	0.010	0.060
73/03/16	12	45	0.459	3.570	0.350	0.068	0.152
73/04/08	09	05	0.052	2.050	0.120	0.014	0.065
73/04/18	09	10	0.022	3.[illegible]30	0.580	0.012	0.050
73/05/20	09	00	0.014	1.930	0.[illegible]75	0.006	0.050
73/05/30	08	35	0.010K	2.100	0.110	0.011	
73/06/09	08	40	0.012	2.[illegible]00	0.013	0.004	0.047
73/07/22	08	45	0.010K	1.150	0.024	0.016	0.040
73/08/19	09	30	0.016	2.610	0.105	0.011	0.076
73/09/23			0.088	0.840	0.060	0.030	0.055

K VALUE KNOWN TO BE LESS THAN INDICATED

STORET RETRIEVAL DATE 74/12/30

277645 ES277645
46 40 00.0 092 24 30.0
ST LOUIS RIVER
27 7.5 CLOQUET
T/ST LOUIS BAY
ST HWY 39 BRDG W THOMSON DOWNSTR RESRVR
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	17 00		0.080	1.000	0.105	0.017	0.079
72/11/12	09 15		0.150	1.300	0.168	0.015	0.052
73/01/21	10 15		0.980	1.640	0.550	0.170	0.315
73/03/18	12 15		0.420	1.850	0.320	0.069	0.155
73/04/09	09 20		0.340	1.760	0.073	0.021	0.085
73/04/19	09 15		0.353	1.340	0.144	0.033	0.075
73/05/20	09 20		0.015	2.700	0.048	0.007	0.055
73/05/30	09 00		0.010K	1.980	0.190	0.012	0.250
73/06/09	09 10		0.010K	2.600	0.047	0.023	0.072
73/07/22	09 00		0.132	1.200	0.085	0.066	0.150
73/08/19	10 15		0.020	1.470	0.115	0.020	0.080
73/09/23			0.087	1.050	0.078	0.032	0.090

K VALUE KNOWN TO BE LESS
THAN INDICATED

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STORET RETRIEVAL DATE 79/12/03

21ABCL [illegible]
4A 37 00.0 090 24 00.0
5 MARION SILVER CREEK
27 7.5 QUADSMALL
1ST LOUIS HAY
PIPE IN QUADSMALL UNSTAB CONTAIN 30 MINS
11 VALES 2111204
" 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	[illegible] MG/L	[illegible] TOTAL MG/L	[illegible] WHOLE MG/L	[illegible] DISS-US WHOLE MG/L	[illegible] DISS-ICP MG/L P
73/04/04	09 30		[illegible]	1.[illegible]	0.036	0.012	0.050
73/04/13	10 10		[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]
73/06/04	09 40		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
73/08/13	10 45		[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]

STORET RETRIEVAL DATE 74/10/30

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 2776C2          LS2776C2
46 37 30.0 092 22 30.0
S BRANCH SILVER CREEK
27      7.5 WRENSHALL
T/ST LOUIS BAY
BRDG IN ST PARK .5 MI NE BELOW WENSH STP
11EPALES                2111204
4                       0000 FEET  DEPTH
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DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	16 30		0.960	0.100K	0.038	0.008	0.011
72/11/12	08 50		0.940	0.190	0.061	0.009	0.009
72/12/17	15 40		1.000	0.300	0.115	0.005K	0.010
73/04/09	09 00		1.060	4.030	0.115	0.008	0.010
73/04/18	09 35		1.100	4.500	0.620	0.007	0.010
73/05/20	09 45		0.990	3.200	0.066	0.005K	0.010
73/05/30	10 00		0.980	1.150	0.066	0.007	0.660
73/06/09	10 15		0.930	0.540	0.260	0.005K	0.015
73/07/22	09 30		1.020	0.290	0.007	0.009	0.015
73/09/19	11 15		0.540	1.600	0.024	0.035	0.430
73/09/23			0.970	0.450	0.017	0.010	0.010

K VALUE KNOWN TO BE LESS THAN INDICATED

ST LOUIS METROPOLITAN AREA

[illegible] 21141204 [illegible] 0032000

[illegible] 38 45 00.0 090 07 30.0

[illegible]

21 15 [illegible]

[illegible]ST LOUIS MAY

ST LOUIS MAY

[illegible]EPALES

4

21141204

0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO3+NO2 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/15 24 00									
CP(T)-									
73/01/16 24 00			0.150	21.300	8.800	3.700	5.500	14.100	13.500
73/02/13 24 00									
CP(T)-									
73/02/14 24 00			0.250	22.600	5.600	3.200	5.850	13.900	14.200
73/03/15 12 00									
CP(T)-									
73/03/16 12 00			1.150	10.500	2.600	1.320	3.100	21.600	15.000
73/04/12 12 00									
CP(T)-									
73/04/12 24 00			0.410	17.000	5.000	3.400	5.000	16.400	16.700
73/05/21 12 00									
CP(T)-									
73/05/21 24 00			0.202	20.600	5.300	3.500	7.600	16.100	17.100
73/06/14 12 00									
CP(T)-									
73/06/14 24 00			0.165	15.400	3.800	2.850	5.503	16.000	16.200
73/07/23 12 00									
CP(T)-									
73/07/24 12 00			0.043	17.000	4.900	2.520	5.750	15.400	13.600
73/08/28 12 00									
CP(T)-									
73/08/29 12 00				14.600	3.058	1.420	4.500	22.400	19.600
73/09/22 12 00									
CP(T)-									
73/09/23 12 00			0.350	17.500	7.300	2.733	5.430	14.500	17.200
73/10/17 12 00									
CP(T)-									
73/10/18 12 00			0.640	19.000	2.730	3.200	5.500	12.800	15.500
73/11/14 12 00									
CP(T)-									
73/11/14 12 00			0.420	18.500	1.190	2.540	5.500	15.500	15.700
73/12/29 00 00									
CP(T)-									
73/12/29 24 00			0.32[illegible]	19.000	2.251	3.525	7.400	14.500	14.900

STORET RETRIEVAL DATE 74/10/30

277651 PR277651 P092000
46 45 00.0 092 07 30.0
DULUTH
27 15 DULUTH
D/ST LOUIS BAY
ST LOUIS BAY
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/01/16	00 00								
CP(T)-			1.520	20.000	9.800	3.800	7.305	10.200	10.700
74/01/16	24 00								

STORET RETRIEVAL DATE 74/12/20

277652 PR277652 P0008699
46 43 30.0 092 27 00.0
CLOQUET
27 7.5 CLOQUET
T/ST LOUIS HAY
ST LOUIS RIVER
11FPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/31	11 00								
CP(T)- 73/01/31	13 00		0.540	35.200	10.720	3.600	6.800	1.100	1.140
73/02/28	11 00								
CP(T)- 73/02/28	13 00		0.380	36.600	7.700	3.600	7.350	1.090	1.080
73/04/02	11 00								
CP(T)- 73/04/02	13 00		1.400	28.300	5.300	3.300	9.550	1.640	1.680
73/04/30	11 00								
CP(T)- 73/04/30	13 00		0.640	28.000	6.300	3.300	12.000	1.840	1.670
73/05/31	11 00								
CP(T)- 73/05/31	13 00		1.150	24.000	4.070	3.140	7.800	1.670	1.740
73/07/31	11 00								
CP(T)- 73/07/31	13 00		0.260	25.000	8.200	3.200	9.600	1.340	1.360
73/08/31	11 00								
CP(T)- 73/08/31	13 00			20.900	2.620	3.140	7.870	2.130	2.150
73/09/28	11 00								
CP(T)- 73/09/28	13 00		1.050	22.100	3.700	3.780	10.500	1.660	2.000
73/10/31	11 00								
CP(T)- 73/10/31	13 00		1.320	25.000	4.600	3.700	8.800	1.860	2.130
73/12/04	11 00								
CP(T)- 73/12/04	13 00		0.040	23.000	3.000	0.120	7.800	1.880	1.910
73/12/31	11 00								
CP(T)- 73/12/31	13 00		1.240	31.000	6.300	4.000	10.500	1.610	1.480

STORET RETRIEVAL DATE 74/12/30

277653 PR277653 P012000
46 45 30.0 092 07 30.0
DULUTH WEST PLANTS
27 15 DULUTH
D/ST LOUIS BAY
ST LOUIS BAY
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/02/13	11 00								
CP(T)-			0.300	35.000	15.600	4.400	7.700	0.855	1.080
73/02/13	14 00								
73/03/14	11 00								
CP(T)-			0.750	18.900	2.200	2.400	5.500	2.300	1.200
73/03/14	14 00								
73/04/12	11 00								
CP(T)-			0.470	27.000	9.100	3.600	6.500	0.312	0.344
73/04/12	14 00								
73/05/21	11 00								
CP(T)-			0.330	26.000	8.800	3.900	7.300	1.260	1.400
73/05/21	14 00								
73/06/15	11 00								
CP(T)-			0.154	25.000	4.400	4.060	6.900	1.200	1.500
73/06/15	14 00								
73/07/17	11 00								
CP(T)-			0.320	32.000	12.000	1.400	10.500	1.240	1.210
73/07/17	14 00								
73/08/15	11 00								
CP(T)-			1.540	10.500	0.800	1.820	4.100	1.840	1.350
73/08/15	14 00								
73/09/19	11 00								
CP(T)-			0.330	30.000	19.000	4.700	6.900	1.320	1.390
73/09/19	14 00								
73/10/17	11 00								
CP(T)-			0.380	28.000	9.700	3.360	6.000	2.290	1.530
73/10/17	14 00								
73/11/14	11 00								
CP(T)-			0.240	31.500	14.000	4.300	7.700	1.500	1.280
73/11/14	14 00								
73/12/28	00 00								
CP(T)-			0.640	50.000	12.600	3.300	5.400	0.274	0.356
73/12/28	03 00								
74/01/13	00 00								
CP(T)-			0.440	23.000	16.000	4.100	6.200	0.400	0.320
74/01/19	03 00								